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ON SOME POINTS IN REGARD TO COLOR-
BLINDNESS.

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THE practical questions connected with color-blindness have been brought very prominently before the public within the past two years, and have been acted upon by state legislatures and the general government as well as by various private corporations. The necessity of distinguishing signals correctly is of such obvious importance in railway operating and in navigation that it is no wonder that the subject has attracted public attention. It is more a matter of surprise that the practical importance of an infirmity that has been recognized for a hundred years or more, and that has been studied more or less by physiologists for half that period, and the common occurrence of which has been well known, should not have been earlier recognized. Men had been sailing ships and running locomotives many years under the present systems of colored signals, and their capacity had never been questioned until, under the present tests, they were found defective and disqualified. It cannot, nevertheless, be assumed from this that the present agitation of the subject is needless; it may be that only one-tenth of one per cent. of accidents by rail or sea has, amongst its causal factors, this defect of color-vision, and yet the public has the right to claim protection against even this remote possibility of danger. The ques-

tion only remains as to just what is necessary for this protection and how it is to be afforded. If color-blindness of certain kinds and degrees does not disqualify the individual from correctly distinguishing signals, as is claimed by Mr. William Pole,* then the practical importance of the defect is greatly diminished, if not altogether destroyed, as regards these occupations. Again, if this infirmity is curable by exercise or education, as is held to be the case by Dr. Favre, who was himself one of the first to call attention to the practical points involved, then the whole subject is deserving of far less importance than is nowadays attributed to it. If either of these views is correct, it is a reasonable presumption that a person in constant exercise of his perceptive powers on the distinction of colored signals would be able to overcome or compensate for this particular defect, so far as all practical purposes are concerned, while still, it may be, exhibiting it in the plainest manner to the usual tests. Some facts point very strongly in this direction; the recent examinations of pilots and engineers have revealed cases of color-blindness where it was utterly unsuspected, and in persons who had acceptably filled positions for many years that required daily and almost hourly exercise and test of their ability to correctly distinguish colored signals.

The object of this paper is to discuss certain practical points in relation to color-blindness that appear to have been heretofore too little noticed. First among these is what I may call the psychic element in the disease or defect, which, I think, is quite an important one in many cases. The seat of color-blindness has been commonly spoken of as in the retina or conducting-fibres to the brain, and many writers have apparently acted entirely on this assumption. The usual way of stating the Young-Helmholtz

* *Contemporary Review*, May, 1880.

theory of color-perception is that there are three sets of nerve fibres, conveying respectively impressions of red, green, and violet, or that there are three sets of retinal perceptive elements with such functions. The Hering theory is commonly stated as if there were three kinds of physiologico-chemical changes taking place in the retina, and producing, according to their stage and degree, the shades and tints of black and white, blue and yellow, and red and green. Nerve fibres cannot be considered, in the light of our present knowledge of physiology, as anything more than mere conductors; their functions depend solely upon their terminal apparatuses, and of these the central ones are as essential and more important than those of the periphery. We can follow the light through the dioptric mechanism of the eye to the rods and cones of Jacob's membrane, and then the process changes from a physical to a physiological one, and, however much we may speculate in regard to the function of the rods and cones, the exact manner in which the luminous impressions are received by them to be converted into nervous impulses, is absolutely unknown. From this point on, the visual mechanism is a sort of physiological telegraph, the retina being simply the sending apparatus, the optic nerve the conductor, and the receiving of the message and its delivery to consciousness are, of course, accomplished somewhere within the cerebrum. The process may be interrupted at any point of the route, the retina may be an imperfect instrument, the conducting fibres may be out of order, the centre at the base of the brain may be defective, or, finally, the conveyance to the centres where the impression is taken cognizance of by consciousness may be retarded or obstructed. This is the case as regards all sensations, and errors and delays are much the most likely to occur with our more complex ones, such as that of color, which is so often found deficient in

otherwise normal individuals. The exact locality of this defect of color-perception is of some practical as well as theoretical importance. In pathological cases it is sometimes accompanied with retinal disease, but this is not so with the congenital forms of color deficiency. If there is in these latter any retinal defect, we might hope, with the modern appliances for microscopic research, to find some structural alteration. A case of the *post-mortem* examination of a congenitally color-blind eye, has not, so far as I know, occurred since the death of Dr. Dalton, and then, the minute anatomy of the retina being at the time unknown, the investigation was confined to the humors of the eye, with, of course, a negative result. But if the retina is the part usually involved in color-blindness, or, rather, if correct color-perception usually depended on the healthy condition of the retina or the rods and cones, we might expect to see it impaired with whatever affected their nutrition, while, in fact, we do not find it necessarily abnormal with either an anæmic or a congested retina, or even with some serious retinal alterations that may affect the general visual power. The fact that color-perception varies in different portions of the retinal field, and especially decreases toward the periphery, does not appear particularly significant in this connection, for all the other niceties of vision follow similar rules. That the retina is a mechanism, the perfection of which is essential to correct color-vision as it is to all sight, is beyond question, but that color-blindness necessarily, or even generally, is due to its defects is extremely doubtful.

The grounds for referring the defect of color-perception to the higher cerebral centres seem much stronger. But there, also, direct anatomical evidence is lacking; we have no pathological facts, so far as known to me, of cerebral lesions directly connected with color-blindness. There are,

however, numerous clinical observations that point strongly in this direction, and some that are scarcely, if at all, intelligible with any other interpretation. Such are the cases of color-blindness in hysterical and hypnotic conditions, and those observed in certain cerebral diseases in which there is, so far as we know, no retinal or optic abnormality. Such a case as one mentioned by Charpentier in a recent paper,* as observed by him in Landolt's clinic, in which there was hemiopia limited to the color-vision, is very positive evidence in this direction, though it does not necessarily indicate a disorder as high as the perceptive centres. In addition, we have the facts of colored phantasms in cerebral disease. A lady of my acquaintance, who is subject to occasional severe migrainous attacks, has them sometimes preceded by a loss of power to perceive any color except red, which tinges all objects; and Dr. J. S. Jewell has described to me a case of a patient of his own who has, preceding his headaches, a brilliant play of colors occupying just one-half the visual field, the other half being normal. We have also, as instances, the color auras of certain epileptics, and it is needless to further multiply instances of this kind.

If we could obtain the testimony in full of all intelligent partially color-blind individuals, we could probably obtain some quite significant facts. My own experience seems to me somewhat to the point. I am partially red-green-blind, not very much so, but to a slight extent. My eyesight is excellent, V. $\frac{20}{20}$; a slight myopic astigmatism, $\frac{1}{16}$, or less, in the vertical meridian, is of no practical importance as a defect. The optic nerve and retina are healthy. I see a continuous colored spectrum from beyond the potash line to the extreme violet. The lithium line is a very beautiful and typical red, and if any portion of the spectrum is cut off or uncolored at the red end it must be extremely slight. I

* Read before French Assn. Adv. Sci. (Rep. in *Progrès Médical*, 1880). This JOURNAL, Oct., 1880.

recognize all the spectral colors as distinct in tint, except, perhaps, indigo, which seems only a variety of blue. I do not see any gray or uncolored stripe in the blue-green; in fact, my perception of spectral colors seems to be only weakened, not in any important respect lost. Yet, in pigments I am constantly liable to confusion, and frequently confound colors that to other persons are quite distinct. Sometimes, in using Holmgren's first test with the green skein, I put in all the usual confusion colors, and some that are not usually given as such. There is a special tendency to confuse certain browns with dark yellow-greens. The peculiar feature, however, that bears upon the point now under consideration, is that when I see two colors as alike, a closer inspection, requiring sometimes only a few seconds, sometimes even a minute or more, brings out a difference, not in shade or tone, but in tint, and I can generally correctly name the color. Then, again, in using Holmgren's test No. 1, I have to give my whole attention to the *nuances* of green, at one end or the other of the series, separately—that is, I am obliged to sort out the blue-greens by themselves, and in so doing I scarcely notice the yellow-greens, and *vice versa*. If this is not done, I leave in the pile of mixed skeins either a number of well-marked blue-greens or yellow-greens, which I readily recognize by themselves. It appears that my color-perception is not equal to covering the whole range of greens at once, though recognizing their common character when taken separately.

Again, in looking at a cherry-tree, or other dark foliaged tree with red fruit, I first see only a uniform dark green, but longer observation brings out the red color of the ripe fruit. This is independent of the form, for the color can be seen without my taking note of the form, and when the fruit is abundant and clustered, at a distance too great to well distinguish the form. Another instance of this peculiarity of

my color-vision is, that in looking at a certain painted glass window, a rosette of alternate leaflets of a yellowish-green and a tint of red of very nearly the same illumination and pattern, appears to me at first of all one color, but continued observation brings out the red, and afterward, as long as I continue to look at it, it is not possible for me to make the same confusion. I have frequently repeated this experiment, and generally with the same result. I say "generally," for I find my color-sense varies from day to day, and at times I distinguish colors more quickly than at others. On one occasion, with a perfectly new set of worsteds that I had never before tried, I was able to pass all of Holmgren's tests without making any notable mistakes or exhibiting anything more than a tendency to them. This, however, does not often happen, and more frequently this test would indicate, I think, a much more deficient color-sense than I really possess. I constantly observe this variability of my power to perceive colors, and have tried to make out its cause, or some rule by which it is governed, but so far with no result. I have a good faculty of mental imagery, and can generally recall rather vividly the color of any familiar object, and have sometimes thought that this might also be at fault when color-perception is at its worst, but careful observations in this regard have not verified the supposition. In fact, color-memory and color-perception appear to be somewhat independent of each other in my case, or, rather, the former does not fully reproduce the latter.

The fact that in the cases I have described I see the color or *nuance* and not the shade or tone, is to me a subjective certainty. The only way I can easily demonstrate it to others is by correctly naming the tint after it has impressed itself upon me, which I have often done. Indeed, the fact that two colors sometimes, at first sight,

look exactly alike to me, though afterward they appear different in tint, would seem to indicate that they were the same in shade, especially if I am to be credited with the usual acuteness in that direction of the partially or wholly color-blind. My power of discrimination in this respect is said to be, in reality, quite acute.

It appears highly probable that this psychic element enters much more largely into partial color-blindness than has been generally supposed. All of our senses have to be educated in infancy, and to this is possibly due, to a very great extent, the absolute vacancy in our minds in regard to the earlier months and years of our existence. The infant sees, that is, the light affects its optic nervous mechanism, but it conveys no adequate idea to its mind till, by the coöperation of its other senses, a true perception of the nature and relationship of things is evolved. Most people are still in the condition of infancy as regards the refinements of certain of their senses, the auditory sense, for example, which in some respects is so comparable to that of sight. In all these cases it is the higher centres that are at fault, and if there is any defect in the lower mechanism for receiving impressions, it will be likely to exaggerate itself in the cortical changes that are correlated with conscious perception. It may easily be, and indeed it appears highly probable, that a deficient early training and a lack of special observations of colors in early life, when the cerebral centres are receiving those first impressions that most strongly influence their organization, may have as their result in adult life a defect of color-sensibility, varying in degree from scarcely perceptible enfeeblement to pronounced partial color-blindness, or to dyschromatopsia, as in my own case. Disuse abolishes or weakens functions in the brain as in other organs, and there is no good physiological reason why special cerebral organs or centres may not be thus affected.

It may even be that to this, combined with heredity, is due the relatively greater frequency of the defect in the male sex.

I have not met with much mention in medical literature of this retardation of color-perception, which I myself experience. In his work on color-blindness, Dr. B. Joy Jeffries mentions incidentally, in one place, a slowness of color-perception which cannot, however, be very marked, for it is plain that by the test he usually employs, any hesitation or actual tendency to put in confusion colors is counted as color-blindness. He also gives an account of the examination of some pupils in an institute for the blind, who had still an ability to perceive colors. One lad, the least blind of them all as to form, etc., was able to name the colors of various objects correctly, but with hesitation; he said "he did not get hold of colors very well." The account is suggestive of the same difficulty that I myself have experienced, but the boy's partial blindness in other respects affects its value in this relation.

Ott and Prendergast,* in a paper on the rapidity of perception of colored lights, briefly allude to some practical points involved. The differences they noted in this respect are too slight to be exactly comparable with those I have described. They simply observed the differences of personal equation that probably exist more or less in every individual, while in my own case there seems to be a slowness of cortical functioning in the perception of certain tints, which can be to some extent overcome by conscious mental effort, and which, as I shall attempt to show, can be improved by education.

All these facts appear to indicate that, in some cases at least, the perception of color is largely a mental process involving a considerable element of time and attention, and

* This JOURNAL, April, 1880.

not a simple sensation. The higher cortical centres, therefore, must be the seat of the defect. The mental effort that is required is much like that needed to select a certain sound out of a number, such, for example, as that of a certain instrument or part out of an orchestra or chorus. The loud ticking of a clock may be as distinct as any other sound in a room, and yet make no impression upon consciousness until, by what is sometimes a labored direction of the attention, the nervous impulse reaches the seat of consciousness from the auditory apparatus, upon which the vibrations have all the while been acting. It appears to be in much such a way as this that my perception of certain colors, or rather of certain tints and shades of color, takes place; they do not impress themselves upon my consciousness until by a special effort my higher perceptive centres have been particularly devoted to their recognition. And when this concentration of attention is given I am all the more blind to other tints; I cannot see the yellow-greens well when looking for the blue-greens, and *vice versa*.

It is not an unnatural or unjustifiable inference that this perception, requiring a mental effort, may be modified by education; it is the rule that the mental powers improve by exercise. This brings me to the second point to which I wish to call attention,—that of the curability or modifiability of color-blindness.

It is generally assumed—there are very few who hold to the contrary—that congenital color-blindness is incurable. It may, perhaps, be admitted as highly probable that when absence of power to distinguish all colors, or any one fundamental color, is complete, that there is very little or no possibility of a change taking place. In this case there is no basis upon which to work; if, for example, the case is one of complete red-blindness, there is then no original sen-

sation or perception of red to be cultivated or educated.* But when this dictum of the incurability of color-blindness is so extended as to apply to all the partial phases of the defect, it seems to me unphilosophical and unphysiological. If the defect is only an imperfect or retarded perception, as in my own case, located in the higher cerebral centres and partially compensated for by mental effort, the case is quite different from that of a complete absence of any fundamental color, both in its nature and its prognosis. There is, in such a case, no good ground for denying the possibility of an improvement or modification of the condition, and there are abundant reasons to the contrary. It would be against all analogies if it were not so. I will, however, here again cite my own experience.

Ever since childhood I have been aware of a difference in color-perception between myself and others. My earlier recollections in this line are of inability to see more than two colors—yellow and blue—in the rainbow, and of being a rather notable failure in the strawberry excursions of boyhood. The redness attributed to the rose and certain other flowers was also a puzzle to me. I did not come to a full appreciation of my defect till I was nearly twenty years old, when I had one day a dispute about the colors of a certain area of a map. Then I began to notice my color-sense and exercise myself on colors. Red, or what was called such,

* The statement of Cohn (*Deutsch. Med. Wochenschr.*, 1880, No. 16) that by hypnotism he was able to produce correct color-perception in two totally color-blind persons, and in one partially color-blind, appears to contradict this view, and to show that, even in these cases, there is a latent capacity for color-perception. That is, if there was no error in Cohn's observation. I have as yet seen only his preliminary communication, and do not know the full details of his experiment. All the subjective phenomena of hypnotism have, so far as I have been able to observe in my own experiments, apparently depended upon external suggestion for their incitation at least. If, therefore, I am allowed to offer a hypothesis to account for these cases, I should say that there was, from his suggestion, either verbal or inferred, that their color-sense would be modified by warming the eye, such a concentration of attention on this special faculty on the part of these three persons that, with the usual intensification of single faculties thus excited in the hypnotic state, their latent color-sense was excited into action. Their total color-blindness can be regarded, therefore, as only aggravated psychic dyschromatopsia or normal slowness of color-perception.

seemed to me to include a large range of colors from scarlet, which appeared to me as the type, to certain tints that seemed to me much more blue than red. Indeed, some tints called red by others appeared to me almost typically blue. I have no recollection of ever recognizing purple and violet in my childhood, and I do remember wondering why they were called anything more than varieties of blue. The exercise in colors which I gave myself taught me to recognize purple in some of its varieties when I was about twenty-one years of age. Shortly after this I had occasion to make a trip by water, and the importance of the recognition of colored signals in navigation occurring to me, I took pains to notice the side-lights of vessels, and I found my vision quite defective. I also noticed particularly that while at this time I could distinguish purple tints if I gave my attention to them, I had a very strong tendency to confuse them with the blues. I also noticed the variability of my color-sense at this time. I cannot say just when the change in my vision occurred; it must have been gradual, but at the present time I readily distinguish the purples and violets, and have only a very slight tendency to confound the lightest and least saturated of them with the blues, excepting at times when my eye for colors is unusually bad. The various tints of red are all distinguishable and quite different in appearance to what they were formerly; this is especially the case with the crimsons and rose tints. Within the past two years I have repeatedly tested myself with colored lights under practical conditions, and find that I make very few, if any, mistakes. There seems, in fact, to be a very marked improvement in my color-vision over what it was formerly.

It may be said by objectors that my present ability to distinguish colors that I formerly confounded, is due, not to any actual improvement or change in my power to per-

ceive them, but to practice with light and shade. All I can say to this objection is that any such assertion is not true, if I am to take the testimony of my own consciousness, rather than accept the *a priori* assumptions of others, who can by no possibility share it. I perceive light and shade at once, and better, I think, than the average individual, but the difference in tint between two colors that I am likely to confuse, such as very pale green and drab, and dark-yellow green and certain browns, only reveals itself to my eye slowly, and sometimes only after careful comparison, the illumination remaining all the while the same.

The practical importance of the slighter degrees of color-blindness, in some cases at least, is very much lessened, if it is admitted that the defect is located in the higher centres of the brain; that it amounts in some instances only to a functional defect of cortical cerebation, to be compensated for to a great extent by mental effort and attention; and that it is improvable by education and exercise. The usual test employed in this country for the examination of railway employees and pilots, that of Holmgren, makes, however, no allowance for this variety of color-defect. Dr. Jeffries, the principal authority on the subject in this country, says, in his directions for the use of this test, referring to the colored plate accompanying it: "If the person examined takes any of the confusion colors (1-5) to put with the green, he proves himself color-blind; or even if he seems to want to put them together." This rules out all hesitation, and condemns at once as defective any one who exhibits any uncertainty requiring mental effort or comparison. Holmgren's test has the advantage of detecting very slight abnormalities of color-vision, but it also has the defect of exaggerating them. As it is often used in this country, the person to be examined is required to select out all tints and shades of the color of the test skein, and in this

case, if it is not supplemented by some other test, it is liable to do injustice. There are many persons whose vision for colors is as good as the average, who still have idiosyncrasies in regard to the relationship of colors to each other, for instance, as to the exact limits between blue-greens and greenish-blues, yellow-greens and greenish-yellows, etc., and without going so far as to say with Stilling,* that by it a perfectly normal-eyed person may be made out color-blind, there is no question but that there is in it, when thus made, between examiner and examinee, a very large chance for erroneous diagnosis. Although my own defect is now, as nearly as can be ascertained from all the various tests employed, a slightly feeble or retarded perception of red and green, Holmgren's test No. 1, thus applied, may make me out as completely color-blind as the man who has no perception or sensation of red and green whatever.

When we consider that a man's whole livelihood may depend upon the result of the examination, the advisability of avoiding unnecessary mistakes is sufficiently obvious. Therefore, Holmgren's test should, I claim, be always carefully supplemented with some other that approaches more nearly the practical conditions that the color-sense must meet, in cases of incomplete color-blindness. Donder's test with lights seen through colored media in apertures of various sizes, appears to me much more satisfactory for practical purposes than the generally employed one of Holmgren.

I might discuss here at length the vision of the color-blind, and examine the claim made by Mr. Pole, that the red-blind individual, seeing red light as a dark saturated yellow, could yet distinguish it from the green, especially if the blue-green, the complementary color to red, and the tint advised by M. Redard in a recent report to the French government, is used instead of the manifold tints now em-

* Ueber das Sehen der Farbenblinden, p. 77.

ployed. My object in this paper, however, has been to notice the psychic element in partial color-blindness and its necessary consequence, the possibility of cure or modification of the defect. The following conclusions appear to me to be logically justified by the facts:

1. Color-blindness, when partial and incomplete, is, in some instances at least, a functional defect of the higher cortical centres concerned in sight. It amounts in some cases to merely a retardation of perception of certain colors, and may be compensated for to some extent by mental effort and attention.

2. Inasmuch as this form of color-defect is a mental one that can be more or less overcome by effort, there is a possibility of its modification, if not of its complete cure, by exercise and education, as it is the rule that the mental powers are improved by exercise. Its practical importance is, therefore, somewhat modified by this fact.

3. Holmgren's test, while revealing very slight defects of the color-sense, also magnifies them, and, as usually employed in this country, takes no account of this mental element. It should, therefore, in justice to the examined, be supplemented in all cases of partial color-blindness by other and more practical tests.

